Life course of place

Life course of place: a longitudinal study of mental health and place

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Abstract

A multitude of studies have demonstrated that individual circumstances *throughout* life influence subsequent health and well-being outcomes. The life-course perspective emphasises that health is affected by the accumulation of social and economic (dis)advantages over an individual's life but, importantly, also that there can also be critical periods where the effects of exposure can be greater. Yet few researchers have applied a life-course perspective to the study of health and place, which has resulted in a partial understanding of the dynamics of person-health-place relations. By explicitly recognising that places are spatial-temporal products, and applying a novel longitudinal life-course approach, this study examines the opportunities for incorporating aspects of place into a life course framework. The focus is the influence of neighbourhood social deprivation and provision of local green space on mental health (particularly anxiety and depression). Historical and contemporary place-based information from the Lothian region of Scotland are combined with data from a cohort of individuals born in 1936 (the Lothian Birth Cohort 1936) to consider the influence of these environmental factors over the life course on mental health outcomes later in life. The results establish the utility of the life course of place approach, and demonstrate how this concept can be operationalised using historical data sources. The findings suggest that, after adjustment, residing in the most socially

disadvantaged neighbourhoods in childhood was detrimental to mental health outcomes at age 70. Further, green space provision in early life environments is related to mental health outcomes in later life, but any effect may be restricted to those residing in socially disadvantaged places, and dependent on the specific mental health outcome being considered. The findings emphasise the potential of the life course of place approach for enhancing the evidence base considering the relationships between health and place.

Introduction

In recent decades there has been growing interest in how place matters for a range of health-related outcomes, practices and experiences. Contextual factors, including the 'opportunity structures' (housing quality, safe and secure employment, physical environments, public infrastructure etc.) and 'collective social functioning & practices' (local norms, crime rates, neighbourhood reputation, social capital and cohesion etc.), have been shown to be prerequisites for positive health experiences (Macintyre *et al.*, 2002). Places may be both 'pathogenic' (health damaging) or 'salutogenic' (health promoting), and implicated in a diverse range of health-related outcomes including physical and mental health, health behaviours and health care utilisation. Further, placed-based processes help to explain the wide and growing socio-spatial divergence in health across most countries, including the UK (Pearce *et al.*, 2016). Yet what is less well established is the temporal dynamism and durability of place, people's transitions through those spaces, and the implications of these processes for social and spatial inequalities in health. Whether people occupy 'healthy' or 'unhealthy' places is therefore a function of spatial and temporal processes that are influenced by how place-based resources become distributed, as well as the (im)mobility of people through different environments (Bernard *et al.*, 2007; Frohlich and Abel, 2014). The novel contribution of the current paper is to consider the importance of these geographical temporalities for health and wellbeing over the life course. The study builds on a new conceptual framework that we have been developing– the life course of place – to conceptualise and, using historical and contemporary data, examine empirically the ways in which the places that people inhabit throughout life (from childhood to older age) influence outcomes in later life (Pearce, 2015).

Whilst previous research has been instructive in furthering our understanding of how places 'get under the skin' to influence health experiences, it can also be critiqued on a number of grounds. Perhaps most notably, work on health and place has been criticised for relying on rather orthodox representations of space and place that have tended to create a false dualism between 'context' and 'composition' and in doing so fail to capture the complex, multiscalar and temporal processes that connect places to health (Smith and Easterlow, 2005). Most studies focus on residential settings as a marker for geographical context when, of course, people are often highly mobile and active in and between a range of settings (work, school, recreation etc.) which are likely to affect the lived experience of place. Whilst there has been much recent interest amongst health geographers in capturing and understanding the role of people's daily 'activity spaces' (Shareck *et al.*, 2014), much less attention has been paid to longer time frames that stretch across the life course. Places are spatiotemporal products that are constantly evolving and fluctuating, with some characteristics staying much the same, whilst other features change and cycle rapidly. Geographers have long realised that 'relational' perspectives of place may be more insightful than more conventional understandings. Relational perspectives, for example, recognise that places tend to operate within complex and *dynamic* networks and are affected by, and affect, wider structural, even global, processes (Curtis and Riva, 2010; Massey, 2005). Therefore, the relations between health and place have to be understood as a set of interrelated processes operating simultaneously at various spatial and temporal scales. Similarly, places are dynamic, responding to local and global processes, with mobile populations moving within and through places over the course of a day, or over their lives (Gatrell, 2011). This conceptualisation is also significant from a policy perspective – if we are to develop policies to enhance public health it is important to estimate the magnitude of

such relationships and understand how far relationships between health and place are generalizable. Yet, these theoretical assertions on the temporality of environment-health relationships are rarely examined empirically, and there is little work considering the ways in which the influence of place on health may accumulate over the life course and/or whether there are sensitive points during life when particular features of place are especially pertinent (Morris *et al.*, 2017). To date, most studies of health and place have relied on cross-sectional analyses, and there are very few empirical studies of how geographical circumstances early in life influence subsequent health outcomes, particularly those later in life. Single point-in-time analyses may overlook processes of change or resilience that embed more contemporary health and inequalities within these locales (Lekkas *et al.*, 2017). This issue is likely to be particularly problematic for health outcomes with long latency periods between environmental exposure and disease onset or with complex associations between environment, behaviour and response that may become habitual over time.

Most recently, there has been a call for new conceptual and methodological work which examines the dynamic histories of places and the implications of this temporal evolution for geographies of health and wellbeing (Lekkas *et al.*, 2017; Pearce, 2015). This organising framework has been labelled the 'life course of place' (Pearce, 2015; Pearce *et al.*, 2016). It draws on the longstanding and important tradition of life course work which focuses on the individual and historical circumstances that accumulate to affect people's health, and adds a geographical dimension to emphasise that historical experiences of place are another important consideration. One of the probable reasons why, to date, there has been such little attention to the role of place in affecting health across the life course has been the lack of provision of data relating to the past environments in which people have lived their lives.

This, alongside the deficiency of data on people's residential histories, has made it challenging, for example, to integrate cohort information with place-based information. The aim of this paper, therefore, is to use the life course of place framework to develop a longitudinal approach for examining the connections between health and place across people's lives. The intention is to establish a method for integrating a range of historical environmental data with information on a cohort of individuals covering most of their lives. We test out this method using the examples of area-level social deprivation and green space, and their potential influence on mental health outcomes. There is more than 20 years of evidence linking area-level socioeconomic measures to a variety of health outcomes and related behaviours, including mental health (Duncan *et al.*, 1999; Fone *et al.*, 2007). Similarly, our focus on green space is appropriate because there is emerging evidence consistently demonstrating that enhanced access to green spaces are related to the psychological health of individuals and populations (Hartig *et al.*, 2014). The approach we propose is novel because previous work has not considered how mental health is influenced by these place-based factors *throughout* life or in later life.

The next section examines the literature that has adopted a longitudinal approach to examine the connections between health and place, and demonstrates that work in this area has focused on a very narrow range of aspects of place, and tended to consider health trajectories over only short periods of time. The paper then outlines our methods for capturing place-based characteristics in the Lothian region of Scotland over a 70-80 year period. This region and timescale was purposively selected to enable integration with a birth cohort of people born in 1936: the Lothian Birth Cohort 1936. We then present our findings relating to the social deprivation and green space trajectories of places across the study

region as well as the analyses examining the influence of lifetime exposure to social deprivation and green space on mental health outcomes at the age of 70.

Longitudinal approaches to examining health and place across the life course

Life course research in sociology, epidemiology and elsewhere has shown that outcomes, including health and well-being, are heavily affected by a suite of social, economic and cultural factors operating *across* the life course. For instance, factors at the start of life, in utero, or even before that, can strongly influence health and other outcomes much later in life (Ben-Shlomo and Kuh, 2002; Kuh *et al.*, 2003). It is widely accepted, for example, that socioeconomic status and health in older age is not independent of social and economic inequalities earlier in life.

Most longitudinal work on health and place has focused on the evaluation of the immediate health implications of a small scale intervention or local natural experiment such as the introduction of cycling or public transport infrastructure (McCormack and Shiell, 2011). Whilst instructive from a policy perspective, this work rarely considers more fundamental changes to places nor monitors the long-term health implications. Even where major environmental interventions, such as a large-scale urban renewal scheme, are considered (Stafford *et al.*, 2008), the interventions tend to be evaluated over quite short periods, typically one or two years. This is perhaps surprising when we consider the literature on health--selective mobility, which has tended to find that residential migration leads to substantial changes to the social and physical settings that people live their lives, which often has lifelong implications for their health and wellbeing (Gatrell, 2011; Pearce and Dorling, 2010; Wilding *et al.*, 2016). Previous work in the UK has tended to show that selective migration patterns help to explain why people with poor physical and mental

health disproportionately locate in more socially disadvantaged places (Tunstall, Mitchell, *et al.*, 2014), although selective migration processes seem to be less significant in understanding their concentration in disadvantageous physical environments (Tunstall, Pearce, *et al.*, 2014). This is important because it means that environmental measure based on place of residence at one point in time may mis-specify environmental exposure (due a person's migration between different types of environments and/or substantial levels of neighbourhood change in the place they reside) and provide inaccurate estimates of the environment-health relationships. Further, studies relying on single point-in-time measures restrict the identification of causal relationships due to concerns about reverse causation.

The few studies of health and place to have incorporated a life course perspective have tended to focus on people's social context at different life stages, usually adopting proxy socioeconomic measures from the corresponding national census (Diez Roux and Mair, 2010). For instance, Curtis et al. (2004) used the Longitudinal Study for England and Wales and found that the socioeconomic conditions of residential environments during early life (particularly area-level economic deprivation and unemployment) were independently related to health experience (mortality and self-report limiting long-term illness) later in life. Other work in the UK used the 1946 British birth cohort (the National Survey of Health and Development) and cross-classified multilevel models to examine the influence of area deprivation (defined as the proportion of the employed population working in partly skilled or unskilled occupations) in childhood, early adulthood and midlife on physical capability (measured as grip strength, standing balance and chair-rise time) at age 53 (Murray *et al.*, 2013). The authors found that standing balance and chair-rise time were independently associated with area-level deprivation of the area in which the respondent lived in childhood and midlife, emphasising the importance of early life circumstances in affecting

disparities in health later in life. Other work has tried to tease out the influence of other - non-residential - social environments on subsequent health trajectories. Another UK study using cohort data from the Aberdeen Children of the 1950s Study examined the combined influence of the socioeconomic status of each participant's school and neighbourhood on self-reported adult health and mental health (Dundas *et al.*, 2014). The findings suggest modest associations between childhood school environment (median odds ratio = 1.08) and neighbourhood environment (median odds ratio = 1.05), and adult self-rated health but not poor mental health.

Other work outside the UK has also focused on the influence of the accumulation of area-level socioeconomic disadvantage over time. Work in Canada using area-level data (e.g. neighbourhood-level measures of household income, education and tenure) from five censuses demonstrated that long-term socioeconomic disadvantage was associated with higher odds of lung cancer, even after adjustment for risk factors such as smoking (Hystad *et al.*, 2013). Similarly, a study in Sweden investigated the influence of accumulating area-level social disadvantage over the life course on self-reported health (more specifically functional somatic symptoms: FSS) at age 42 (Gustafsson *et al.*, 2014). The authors found that, after adjustment for individual-level disadvantage and other confounders, cumulative neighbourhood disadvantage was a significant predictor of FSS in mid-adulthood amongst women but not men, emphasising the health risks of a burdensome life history. Other studies have been less supportive of the cumulative influence of area-level social disadvantage over the life course. For example, in the United States Carson et al. (2007) examined life course data collected from participants of the Atherosclerosis Risk in Communities Study and found little evidence to suggest that cumulative area-level (neighbourhood) socioeconomic status was associated with subclinical atherosclerosis.

Beyond local social context, the only other aspects of place that have been examined in a long-term life course framework is the influence of air pollution (Elliott *et al.*, 2007) and residing in a rural context (Jokela *et al.*, 2009). Hansell et al. (2016), for example, combined data from members of the England and Wales Longitudinal Study with data on air pollution concentrations at residence in 1971, 1981, 1991 and 2001 to examine the contribution of long-term air pollution exposure to mortality (all-cause (excluding accidents), cardiovascular and respiratory mortality). The authors found that associations with air pollution persisted decades after exposure, emphasising that circumstances in earlier life can have implications for health much later in life. In an Australian study using prospective cohort data over a 26-year period, Patterson et al. (2017) found that accumulated residency in a rural area was associated with the development of obesity. Young adulthood appeared to be a particularly sensitive period which may, the authors suggest, be because this a key formative period in which behaviours such as eating and physical activity are firmly established.

Whilst studies such as those described above have been invaluable in enhancing our understanding of place-health relations, the work is limited in terms of the types, range and temporal sequencing of the area-level constructs that have been developed. The reasons why this field remains underdeveloped are likely to include: a lack of *geocoded* longitudinal data following people's social and health trajectories; accuracy of spatial and non-spatial attributes; challenges in identifying and securing historical and geographically-specific environmental data; and inconsistencies in reporting units over time (LLoyd *et al.*, 2012; Murray *et al.*, 2012). Despite the impediments in collecting geographical data over time, the incorporation of historical environmental data with longitudinal data on individuals (including health and wellbeing) offers considerable analytical promise (Diez Roux & Mair, 2010). The current paper demonstrates, using data from the UK, how historical information

collected regarding people's life course environments can be integrated with cohort data to help enhance understanding of the dynamics of places and the implications for health trajectories in later life.

Methods

Study design and setting

This study utilises historical and contemporary area-level information on social deprivation and green space availability appended to the Lothian Birth Cohort 1936 (LBC1936) (Deary *et al.*, 2012). An overview of the data used in this study is shown in Supplementary Figure 1. The LBC1936 participants (born in 1936) were mostly recruited from Edinburgh and the Lothians in Scotland at about age 70, when their N was 1091. In 1947 most of the participants had taken part in a national assessment of their general intelligence (the Scottish Mental Survey 1947). The cohort participants were subsequently contacted at mean ages of 70 years (Jan 2004- May 2007), 73 (Oct 2007- May 2010) and 76 (Jul 2011-Nov 2013). During the regular triennial, in-person testing waves, the cohort undergo extensive cognitive and medical tests, and provide psychosocial information including mental wellbeing.

Residential histories

In order to identify residential histories from birth to present day, the surviving LBC1936 participants were re-contacted in 2014 (mean age 78 years), and requested to complete a 'life grid' questionnaire. The participants were first asked to recall the dates of personal events in their life, and to detail them next to a column containing national and/or global events such as the Falklands War. These events acted as memory prompts for participants

to provide information on their residential address and occupation for each decade. The response rate was 84% (n=593 of the 704 participants still in the study at that time), resulting in a total of 7,423 addresses. Each address was geocoded using Nominatim and Google's geocoder; for the 6% of addresses with a missing geocode (usually because the addresses no longer existed) we manually determined the location using historic building databases (e.g. https://canmore.org.uk). Once we had obtained geocoded data on each participant's residential history, it was then feasible to append the historical and contemporary measures of area-level social deprivation and green space to each individual.

Socioeconomic deprivation measures

Historical measures of area-level socioeconomic deprivation were constructed by transcribing area-level information from various sources including the censuses (1931, 1951, 1961, 1971), the Edinburgh Civic Survey 1949, Medical Officer of Health reports (1930, 1940, 1947, 1950, 1960) and the National Records of Scotland from 1974-1976. This enabled us to build a time series of data for each decade from 1930 to 1970, under the indicators of: population density (persons per acre), overcrowding (percentage of population living more than 2 (or 1.5) per room), infant mortality (infant deaths (<1 year) per 1,000 births), tenure (percentage of households renting their accommodation) and amenities (percentage of households without exclusive access to all amenities) for each decade from 1931-1971. These indicators were selected as they were largely consistent over time and any differences reflected era-specific shifts in understanding and experience of relative poverty (i.e. only minor differences in the data recorded, for example, the number of people per room that constituted overcrowding or the types of amenities considered), but for some decades these data were unavailable (n=5/25) (see Supplementary Table 1).

The data were recorded at different spatial scales (for example 23 wards for the National census and 63 districts for the Edinburgh Civic Survey) which have changed over time. We aggregated all the data to a common spatial resolution (1961 census ward boundaries, n=23) to enable us to implement appropriate strategies for handling missing data on overcrowding in the 1940's, household amenities in the 1930 and 1940's and tenure in the 1930 and 1950's. Given that the same census question was administered for overcrowding in 1931 and 1951 (i.e. percentage of population living more than 2 per room) and tenure in 1946 and 1961 (percentage of households that rent their accommodation) we undertook a linear interpolation to attain measures for the overcrowding in the 1940's and tenure in the 1950's. For amenities we built a linear regression model to predict the 1951 measure using standardised *nuisances* data from the Medical Officer of Health Reports (e.g. number of choked drains cleared, presence of bad smells in dwelling) and several other area-level indicators (e.g. mortality rate, population density). The model performance was assessed by predicting the 1961 amenities indicator (Adj r^2=0.92), and then used to predict an amenities indicator for the 1930's and 1940's. Finally, as we were unable apply the previous two methods to attain a measure of tenure for the 1930's, we therefore used the 1940's measure as a proxy.

To create a historical index of multiple deprivation (1931-1971) we calculated the sum of each indicator's (i.e. population density, overcrowding, infant mortality, tenure, amenities) z-score relative to the full study area for each decade (Norman and Darlington-Pollock, 2017). For 1981, 1991, 2001 and 2011 we used the Carstairs index of deprivation (a widely used measure of area-level measure of social deprivation in the UK), which is a summed z-score from census information on the following indicators: male unemployment, overcrowded households, car ownership and low social class variables (UK Data Service,

n.d.). We also collected data on the indicators above from 1981 to calculate a historical index for this period and found a positive linear association (β=1.12, $p<0.01$)) with 1981 Carstairs index of deprivation. This suggests our historical variables were appropriate measures of era-specific social deprivation. The final step to create the deprivation measures for the cohort was to calculate z-scores across the decade-specific variables in order to ensure the scores were comparable across decades. An estimate of area level deprivation for each of the addresses of each participant (n=4,630) was derived by taking the value of the ward or district where the address point was located. Each participant was given a mean deprivation measure surrounding their residences within the following time periods: childhood (1936-1955), early adulthood (1956-1975), adulthood (1976-1995) and later adulthood (1996-2015).

Green space measures

We constructed measures of green space availability for three time points (childhood, adulthood, later adulthood) using public park availability as a proxy. Public parks were deemed a suitable indicator because they promote social interaction and physical activity to a greater extent than general green space (Richardson et al. 2010). We utilised various open space surveys that recorded public parks in Edinburgh during the 20th and 21st century (Pearce et al. 2016). These data were scanned from paper maps from the Edinburgh Civic Survey 1949 (Abercrombie and Plumstead, 1949) and the Open Space Survey 1969 (Town Planning Department Edinburgh, 1969), georeferenced and converted to GIS vector data using ArcMap 10.1 GIS software (ESRI, Redlands, CA). Contemporary public parks data were derived from the Open Space Audit from 2009 (The City of Edinburgh Council, 2009). Although descriptions of the parks changed slightly between surveys (e.g. public parks and

public recreation grounds), they were consistent in that they were all publicly accessible spaces. For each time point, the percentage of parks within 1,500 m of buffer zone (approximately a 15-25 minute walk) surrounding the participant's home was calculated. Each participant was given a mean green space value from their addresses within the following time periods: childhood (1936-1958), adulthood (1959-1978) and later adulthood (1979-2015). This was repeated with 500 m and 1,000 m buffers in a sensitivity analysis.

Outcome measures

The focus of interest in this study is mental health and we used the Hospital Anxiety and Depression Scale (HADS) which is a validated instrument for determining mental health morbidity—including in older people—and future mortality (Gale *et al.*, 2011). HADS data were collected from the LBC1936 participants via a questionnaire, whereby they were asked to respond to 14 questions with ordinal responses scored from 0-3. Half of the questions relate to anxiety (anxious mood, restlessness and anxious thoughts) and half to depression (low mood, loss of interest and diminished pleasure response) which, when combined, give a maximum total score of 42. The HADS data were collected from the LBC1936 participants in 2006 when they were aged around 70.

Analytical strategy

In the first stage of the analyses we examined the environmental trajectories across the study period for all neighbourhoods in the study area. The intention was to consider the extent to which the environmental characteristics of the places in which the LBC1936 participants have resided through their lives have changed over their lifetimes. Therefore for each time point we aggregated the data to the 1961 ward boundaries and ranked each of the 23 areas in the study region according to the two environmental measures (area-level

social deprivation and local green space) to create graphs of the trajectories for each neighbourhood.

To examine the influence of area-level social deprivation and green space over the life course on mental health at the age of 70 we built negative binomial regression models to account for over-dispersion in the three dependent HADs variables: total score, depression score and anxiety score. Using our measures of area-level social deprivation and public park availability as predictor variables, we tested two life course models: critical periods (childhood, early adulthood, adulthood and later adulthood for area-level social deprivation, and childhood, adulthood and later adulthood for green space) and accumulation (sum of the critical periods).

All models were adjusted for age, sex, father's Occupational Social Class (OSC), childhood smoking status, people per room in childhood home, and the following variables at age 70: OSC, smoking status, alcohol consumption and BMI. The data for the covariates was collected as part of the cognitive testing appointment at age 70, except for father's social class which was obtained via a questionnaire and BMI which was obtained during the physical examination. The multidimensional relationships between individual socioeconomic factors and mental health symptoms are well established (Lorant *et al.*, 2003), and in our study it was important to capture indicators of socioeconomic status during childhood and at the time that the mental health measures were collected. OSC of the participant's father was used as a measure of socioeconomic status from childhood and dichotomised into Professional-managerial (I and II) and Skilled, partly skilled, unskilled (III, IV and V). Childhood overcrowding (number of people per household room) was used as a secondary measure of socioeconomic status. Smoking and alcohol consumption, and adioposity have

all been related to mental health outcomes and are potential confounders of the relationships with the geographical variables (e.g. Taylor *et al.*, 2014). Participants were asked at what age they started smoking and were categorised as a childhood smoker if they responded that they had started before age 16, as per convention (Hopkinson *et al.*, 2014). Smoking status at age 70 was dichotomised as smoker or non-smoker. Normal alcohol consumption was assessed by asking participants how many units they drink each week. Participants' weight divided by height squared provided the BMI at age 70. Adult socioeconomic status was defined by OSC of the participant's main job during their career and dichotomised using the same approach as for their father's OSC. For females, husband's OSC was used if higher than their own.

After undertaking analyses between deprivation and mental health outcomes, and green space and mental health outcomes, we developed two stratified models using dichotomous categories of exposure (by the median) due to small numbers. Firstly, we stratified the deprivation life course models by the sex of the participant, as we hypothesised that associations would be strongest for depression in men and anxiety in women (Bjelland *et al.*, 2008). Secondly, we stratified the green space life course models by the median of area level deprivation (from childhood), as we hypothesised that associations would be stronger in higher deprivation groups due to increased reliance and use of local environments amongst these groups (Mitchell and Popham, 2008). Incidence rate ratios (IRR) (exponents of the coefficients) and 95% confidence intervals are presented. This was a case-complete analysis as missing data were low. All analyses were undertaken in R version 3.3.2.

Results

There were few evident differences between the life-course sample (i.e. those with a Lothian address at each time point) and the full LBC1936 samples (Table 1). A slightly lower proportion of the life-course sample identified their occupation as professional/managerial compared to the full sample at age 78 (51% and 63% respectively). Relatedly, there was a greater proportion of skilled, partly skilled and unskilled participants (45%) compared to the full sample at age 78 (38%). Across the other demographic, socioeconomic and health variables there was little distinction between the two samples.

Life course of place

Figures 1a and 1b demonstrate how places included in this study have evolved over the study period. When places (23 neighbourhoods across the Edinburgh region) are ranked according to the contemporaneous measure of area-level social deprivation, it can be seen that there are examples of places that have consistent high (e.g. Central Leith) and low (e.g. Morningside) levels of relative social deprivation (Figure 1a). However, for other places, between 1931 and 2011 there have been significant changes in their relative rank in neighbourhood deprivation. For example, the area of Sighthill had relatively low levels of social deprivation in 1931 but from the 1950s the deprivation ranking of the area has dropped markedly and by 2011 was the second most socially disadvantaged neighbourhood in Edinburgh. This trajectory is likely to reflect the rapid development of social housing projects from the 1950s and the subsequent disinvestment in this part of the urban area. Some places, such as the city centre area of St Andrews, have become comparatively less socially disadvantaged over the study period, reflecting 'slum clearance' and regeneration initiatives during the post war period.

A similar account can be noted for local green space provision (i.e. public parks) across the city, with some places having consistently high (e.g. Holyrood) or low (e.g. Gorgie-Dalry) levels of provision, while other places show significant change over time (Figure 1b). For example, since the start of the study period, the area of Pilton has evolved from being the lowest ranked area in Edinburgh for park provision to the eighth highest, probably reflecting the significant urban developments – including new park provision - over the study period. Places such as South Leith have dropped down the rankings (from 6th to 14th), probably because there have been few significant new park or housing developments in this area.

Individual trajectories

Figure 2 shows 'heat maps' that illustrate, for the LBC36 participants, the levels of social deprivation and provision of green space in their local neighbourhood at different times during their lives. It can be seen that some participants have resided in places with a relatively high level of social deprivation and green space throughout their lives, whereas others have mostly lived in areas of much lower social deprivation and a less green environments, or have moved between environments with significantly different social and physical characteristics. The heat maps emphasise that, for most LBC1936 participants, their exposure to environmental conditions varied at different stages in their lives (due to changes in their local environments and/or movements between different types of environments), which points to the importance of incorporating this spatial and temporal complexity into environment and health research.

Associations between neighbourhood social deprivation and mental health in older age

To examine the influence of area-level social deprivation over the life course on the three mental health outcomes in later life, we present findings examining: (i) whether area-level

social deprivation at four critical periods (childhood, early adulthood, adulthood and later adulthood) was associated with the three mental health outcomes at age 70 (total HADS total score, HADS anxiety score and HADS depression score); and (ii) if there was an accumulative effect of area-level social deprivation over the life course (Table 2). We also provide an exemplar of the unadjusted results for comparison (Supplementary Table 2). The findings suggest a positive, monotonic relationship between area-level deprivation during childhood and HADs anxiety score (Q4 in comparison to Q1; IRR: 1.23, CI 1.01-1.50), after adjusting for a range of individual-level factors. A similar relationship was found between early adulthood area level deprivation and HADs depression score (Q4 in comparison to Q1; IRR 1.32, CI 1.03-1.70). The strength of the associations tended to be stronger in adulthood compared to younger and older ages, although this was not consistently the case for the depression score. There were also some counterintuitive findings with for example an IRR of 0.75 (CI 0.59-0.97) for the association between quintile 3 area-level deprivation (i.e. moderately deprived) in childhood and the depression score. There was little evidence to suggest a consistent association between area-level social deprivation at any other stage of the life course and the measures of mental health. Summing all the critical periods (i.e. accumulation model) presented some of the strongest effect sizes with the total score and anxiety outcomes but this was a non-linear association (i.e. association greatest in Q3 rather than Q4). In the stratified analyses the accumulation models became the most appropriate, and the effects for childhood deprivation on anxiety and early adulthood deprivation on depression disappeared (Table 3). The stratified models revealed that, for women, being in the higher deprivation quantile during adulthood was associated with an increase in depression score (IRR 1.32, CI 1.03-1.71) although this was the only significant results amongst all of the critical periods models in the table. Again, the accumulation models

provided the strongest results (for Total HADs and Anxiety HADs) with slightly stronger associations for males than females.

Associations between green space availability and mental health in older age

The next step was to examine the influence of green space over the life course on three mental health outcomes in later life. In these analyses, three critical periods (childhood, adulthood and later adulthood) were examined to match the availability of the green space measures. In addition to the main effects, we also provide stratified analyses to examine whether these findings are consistent amongst residents of lower and higher deprivation neighbourhoods.

The first set of results showed that none of the four life-course models demonstrated a relationship between public park availability and the HADS total, anxiety or depression score (Table 4). However, when the results were stratified by the area-level measure of social deprivation (Table 5) we found that for residents of neighbourhoods with relatively high levels of social deprivation, the availability of public parks during childhood was significantly associated with the HADS anxiety score. Being within the highest childhood deprivation quantile and having accumulated a higher exposure to green space during life was associated with a 19% (CI 1-34%) lower anxiety score in later life, after adjustment for individual covariates, although this was not found in the smaller buffer sizes of 500m and 1,000m.

Discussion

The contribution of this paper has been to operationalise the 'life course of place' concept to demonstrate the feasibility of a method for examining the ways in which experiences of

places through the life course might influence health in older age. We have demonstrated this approach by integrating historical environmental data over an 80 year period with information collected from a cohort of participants residing in the Lothian region of Scotland (the Lothian Birth Cohort 1936). We have used the exemplar of poor mental health (after the age of 70) and examined the relationship with the neighbourhood social deprivation and the local provision of green space (using data on public parks). To demonstrate this new approach, we investigated how these place-based factors in early-life, mid-life and later-life are related to subsequent poorer mental health outcomes (at age 70) through accumulative and/or period-specific mechanisms. The findings using this novel approach provided some evidence that early life geographical context and exposure over the life course may be pertinent in understanding mental health outcomes in later life. For instance, residing in the most socially disadvantaged settings during childhood is a significant predictor of some of the mental health measures collected at age 70. Similarly, it appears that the local provision of green space during childhood might be important in influencing mental health in older age, although this association was mostly restricted to residents of more socially disadvantaged places. It was also apparent that this association was dependent on the specific mental health outcome selected; amongst residents of the most social disadvantage neighbourhoods there was evidence for early life influences of green space on mental health for the anxiety measure but not for total HADs score or depression.

That green space availability during childhood (rather than later in life) seems to be particularly important in understanding subsequent mental health outcomes is broadly consistent with earlier work examining the interactive influence of age and green space on mental health. Using data from the British Household Panel Survey, Astell-Burt et al. (2014) found that, for men, green space was associated with better mental health earlier in life

although, for women, the relationship was less clear. The findings of our work also suggest that the influence of green space on mental health outcomes may be stronger amongst those living in more socially disadvantaged areas. This result is consistent with a previous study of 21,294 urban residents from 34 European nations work which found that socioeconomic inequalities in mental wellbeing were narrower for those people reporting better levels of access to green environments, compared to those with poor access (Mitchell *et al.*, 2015). Together, these findings emphasise that environments can be 'equigenic' in that they can have layout and design characteristics that help disrupt the well-established conversion of socioeconomic disadvantage into poorer health outcomes (Pearce *et al.*, 2016).

Operationalising the life course of place concept offers a number of theoretical and analytical possibilities. Firstly, it responds to calls in the literature to prioritise studies of place-health relations that incorporate a longitudinal study design with linkage between appropriate historical area-level data and individual-level health information (e.g. from birth cohorts) (Diez Roux and Mair, 2010). Such work enables investigations into the ways in which different geographical circumstances influence people's health across their lives . It emphasises that geographical influences are not restricted to early years or later years but, rather, can occur across the life course. The life course of place approach enables a better understanding on how environmental exposure during critical periods, such as the formative years (e.g. childhood and adolescence) translates into health in later life. We have, for example, a limited understanding of the dynamics of people-place interactions in terms of behaviour and response, such as how nature acculturation in childhood influences participation in nature-based activities, which may in turn affect the choice of natural environments sought out in adulthood and how nature is experienced (Ward Thompson *et*

al., 2008). Similar arguments can be made for other health outcomes, including how the consumption of alcohol, tobacco and food are affected by early-life geographical constructs such as neighbourhood retail provision or the local norms in respect of these important health-related commodities (Barnett *et al.*, 2016; Jayne *et al.*, 2011; Pearce and Witten, 2010). Thus the life course of place approach can enhance our understanding of critical periods in people's lives, where place-based constructs are particularly pertinent.

Secondly, and related to the above, this approach enables a better understanding of the cumulative influence of environmental factors throughout the life course, and the underlying factors affecting people's varying exposure trajectories. Such an approach can involve considering the mobility of people between different types of health-related environments, which is advantageous in strengthening causal evidence. The migration, mobility and health literature emphasises that residential movement can result in substantial alterations to an individual's social and physical milieu (Darlington-Pollock *et al.*, 2016; Norman and Boyle, 2014). Residential mobility can rearrange people's environmental circumstances with implications for inequalities in outcomes and variations in health trajectories despite, for example, co-location at certain stages in people's lives (Coulter *et al.*, 2016).

Thirdly, the life course of place concept not only enables much-needed longitudinal analyses of the connections between health and place, it also offers the possibility of enriching understanding of the interconnections between historical periods (or eras) and human life experiences and trajectories. More generally, the well-established life course perspective has sought to capture the dynamics and diversity of individual lives through distinguishing people's various social and demographic journeys, including their health, partnerships,

employment and so on. Similarly, the lifecourse of place approach recognises that places are perpetually evolving and can be highly dynamic or, alternatively, change very little (Lekkas *et al.*, 2017) with similar possibilities for variable dynamics of change in the residential population; people's lives are embedded within complex spatial and temporal networks (Curtis and Riva, 2010). Incorporating the developmental history and progression of places and relating these evolutions to contemporaneous and subsequent health geographies is an important research priority. By embracing this complexity, research in the field of health and place can better appreciate that places are the products of spatiotemporal forces and influences, and that these dynamics are important in relating wider structural and socio-political factors (e.g. fiscal policy, labour market changes, poverty, regeneration initiatives and so on) to local particularities, and elucidating how this matters for health. The approach offers opportunities for understanding the role of place in establishing and perpetuating (or disrupting) inequalities in health outcomes. A number of insights are possible and include enriching our appreciation of the role of uneven spatial distributions of environmental 'goods' and 'bads' in individual health trajectories.

Work on environmental (in)justice emphasises that disadvantaged populations often endure the 'triple jeopardy' of social disadvantage, residing in poor quality social and physical environments, and disproportionately poor health (Masuda *et al.*, 2010; Pearce *et al.*, 2010). There have been calls in this work on environmental justice not only to consider the sociospatial distribution of environmental goods but also to prioritise an examination of the *processes* that lead to this spatial arrangement and subsequently to inequalities in outcomes (Frohlich and Abel, 2014). The life course of place approach is instructive because it can enrich our understanding of these geographical processes and help to identify the temporalities and evolution of people's local environments. It can also elucidate who is

'locked' into less healthy social and physical milieu and then how these (im)mobility patterns translate into varying health trajectories. This approach draws on Sen's capability approach whereby people are enabled or constrained in living different types of lives according to how freely they are able to take advantage of the resources available to them (Sen, 1993, 2009). This freedom can, in part, be structured by geographical context, with implications for people's capabilities, or what people are effectively able to do, including engaging in healthy lifestyles and practices. Future work can explicitly examine group trajectories of places and people and then consider whether these assemblages relate to social and spatial differences in health outcomes.

Our study has limitations. Firstly, we relied on retrospective collection of residential address history, which may be prone to recall bias. In addition, our study only includes those LBC1936 participants who were surviving at the time of data collection (2014) when the cohort were in their late 70s. This could introduce a degree of social bias into our work, although there were few discernible differences between the profiles of the life-course sample and the full samples. It may also explain some of the counter-intuitive relationships with neighbourhood social deprivation and mental health that might be accounted for by the fewer respondents surviving in the more disadvantaged areas. This point emphasises the need for cohort studies to collect detailed residential information (and other geographical identifiers) through all data collection phases. Secondly, we were also limited by the number of participants available for the analysis sample due to the strict criteria we applied that focused only on those participants with a residential address in the Lothian region of Scotland for all time points. Thirdly, levels of mobility amongst the LBC1936 participants is likely to be low relative to the general population as recruitment into the cohort relied on the participant residing in the Edinburgh region at age 70. This issue is

potentially pertinent because highly mobile populations are generally at higher risk of negative health outcomes (Tunstall, Mitchell, *et al.*, 2014), and more likely to be exposed to a wider range of environmental settings. Future work could usefully adopt our general approach with a larger cohort of individuals, such as those available in one of the British birth cohorts. Fourthly, there are limitations associated with the area-level measures that we utilised. In particular, we are constrained by the availability of a range of area-level measures that were captured at multiple time points (Murray *et al.*, 2012). Neighbourhood constructs such as levels of crime were not readily available in a useable form and for consistent geographical units. Further, the data we obtained were only available for ten year intervals when social change in urban areas can be more rapid. We were also restricted by the available historical data on green space which only allowed us to capture public parks. More specifically, we were unable to include other types of green space that might also matter for mental health, such as private gardens and allotments. Similarly, we did not include information on other places that might influence mental health such as schools, workplaces or commuting routes. Also of concern was the consistency of definition and meaning across eras, as the importance of particular geographical factors ebbs, flows and evolves. Fifth, the socioeconomic data were only available at the ward-level. Data for smaller geographical units would have captured more localised estimates of exposure and likely more spatial variability between places over time. This approach may have led to different conclusions about the relationships between area-level socioeconomic characteristics and mental health over the life course. Sixth, given that we have completed a number of separate analyses, it is possible that some of the significant findings could have occurred by chance. Seventh, the HADS measure was only available for a single time point (at age 70) and information on previous mental health conditions were not available.

Therefore, it was not possible to identify when any mental health conditions first manifested which potentially restricts causal inference. Finally, the parameters of this concept need to be recognised. Whilst we contend that the approach will prove valuable in enhancing our appreciation of the temporal development of places, and hence enrich our understanding of the connections between health and place, it can only provide insights into a restricted range of static snapshots of place over time when, of course, places are constantly churning and evolving (Andrews, 2017). Complementary methodological innovation will be required to more fully appreciate the complex multi-dimensionality of place and its connections with health.

Conclusion

In this paper we have argued that researchers concerned with the connections between health and place can productively pay closer attention to temporal trends, including an examination of how places may affect health at different (critical) time points in different groups (Morris *et al.*, 2017). By overlooking the temporalities of places, and therefore failing to recognise how places change and evolve as well as the movement of people through places, it is likely that the connections between health and place will be misunderstood or misrepresented. Of course this conceptual assertion raises a number of technical and methodological challenges, not least the collection of place-based information over time and obtaining information on peoples' residential histories. To help understand how places affect people cumulatively, or matter at critical moments in life, we have developed a concept we have called the life course of place. We have successfully operationalised this concept through the combination of historical, place-based data alongside cohort information that captures detailed sociodemographic and health information over time. We

have shown how it is possible to link cohort data with residential histories over an 80-year period alongside temporal environmental data relating to green space provision and area-level social deprivation, and thereby deepen our understanding of the influence of place on health. The empirical finding demonstrated that environmental circumstances in early life, in particular the availability of parks, may have life-long impacts on mental health. We encourage researchers in other countries to adopt the life course of place framework to examine the dynamic relationships between health and place over the full duration of people's lives.

Table 1: Selected Characteristics for LBC1936 sample at age 78 (Mean ± SD; N (%)

Characteristic	Lifecourse Sample at age 78 (n=328)	Full Sample at age 78 (n=531)	Full Sample at age 70 (n=1,091)
Age at wave 1 (years)	69.3 ± 0.71	69.4 ± 0.79	69.5 ± 0.83
Sex			
Female	159 (48)	252 (47)	543 (50)
Father's Occupational Social class (age 11)			
Professional-managerial (I/II)	83 (25)	138 (26)	260 (24)
Skilled, partly skilled, unskilled (III/IV/V)	227 (69)	361 (68)	700 (64)
NA	18 (5)	32 (6)	131 (12)
Childhood Overcrowding (People per room in Home)	1.35 ± 0.76	1.32 ± 0.75	1.38 ± 0.79
Childhood Smoking (Started smoking before the age of 18)			
Yes	61 (19)	97 (18)	226 (21)
Participant's Occupational Social class (age 70)			
Professional-managerial (I/II)	167 (51)	322 (63)	592 (54)
Skilled, partly skilled, unskilled (III/IV/V)	148 (45)	202 (38)	478 (44)
NA	3 (0)	7 (1)	21 (2)
Alcohol Consumption (Exceeding recommendations at age 70)			
No	245 (75)	382 (72)	815 (75)
Yes	83 (25)	149 (28)	276 (25)
BMI (age 70)	27.7 ± 4.32	27.57 ± 4.17	27.8 ± 4.36
Smoking Status (age 70)			
Current	26 (8)	37 (7)	125 (11)
Ex-smoker	136 (41)	235 (44)	465 (43)
Never smoked	166 (51)	259 (49)	501 (46)
Area level Socioeconomic deprivation (z-score index)			
Childhood	0.41 ± 0.91	-	-
Early Adulthood	0.08 ± 0.74	-	-
Adulthood	-0.29 ± 0.84	-	-
Later Adulthood	-0.09 ± 0.88	-	-
Accumulation	0.10 ± 2.56	-	-
Area level green space (% in 1,500 buffer)			
Childhood	9.03 ± 6.65	-	-
Adulthood	8.99 ± 5.34	-	-
Later Adulthood	10.29 ± 6.48	-	-
Accumulation	28.32 ± 14.18	-	
HADS total score (age 70)	7.62 ± 4.37	7.43 ± 4.48	7.68 ± 4.52
NA	2 (0)	4 (0)	5 (0)
HADS anxiety score (age 70)	5.02 ± 3.09	4.81 ± 3.12	4.89 ± 3.18
NA	2 (0)	2 (0)	2 (0)
HADS depression score (age 70)	2.60 ± 2.08	2.63 ± 2.14	2.8 ± 2.2
NA	1 (0)	4 (0)	5 (0)

For continuous variables, mean presented with standard deviation in brackets; For categorical variables, number with percentage in brackets; NA is missing; Percentages may not add to 100 due to rounding

Table 2: Area level socioeconomic deprivation and Hospital Anxiety and Depression score in later life (IRRs and 95% CIs)

Life course model ¶	**Hospital Anxiety and Depression Score**		
	Total	**Anxiety**	**Depression**
Critical Periods			
Childhood			
Ref- Lowest relative dep.	-	-	-
Q2	0.92 (0.77-1.09)	0.96 (0.79-1.16)	0.85 (0.67-1.07)
Q3	0.94 (0.78-1.14)	1.05 (0.86-1.28)	0.75 (0.59-0.97)*
Q4- Highest relative dep.	1.18 (0.98-1.41)	1.23 (1.01-1.50)*	1.08 (0.86-1.37)
Early Adulthood			
Ref- Lowest relative dep.			
Q2	1.03 (0.86-1.24)	1.03 (0.85-1.26)	1.05 (0.83-1.34)
Q3	1.15 (0.95-1.39)	1.16 (0.95-1.42)	1.13 (0.88-1.45)
Q4- Highest relative dep	1.17 (0.96-1.42)	1.10 (0.89-1.35)	1.32 (1.03-1.70)*
Adulthood			
Ref- Lowest relative dep.			
Q2	1.12 (0.93-1.35)	1.07 (0.88-1.31)	1.23 (0.96 (1.57)
Q3	1.20 (1.00-1.45)*	1.19 (0.97-1.45)	1.25 (0.98-1.61)
Q4- Highest relative dep	1.15 (0.94-1.40)	1.15 (0.93-1.42)	1.19 (0.91-1.55)
Later Adulthood			
Ref- Lowest relative dep.			
Q2	1.04 (0.86-1.24)	0.92 (0.75-1.12)	1.28 (1.01-1.63)*
Q3	1.12 (0.93-1.36)	1.09 (0.89-1.34)	1.20 (0.93-1.56)
Q4- Highest relative dep	1.02 (0.83-1.25)	1.01 (0.92-1.25)	1.07 (0.82-1.40)
Accumulation			
Ref- Lowest relative dep.			
Q2	0.96 (0.80-1.15)	0.92 (0.75-1.12)	1.03 (0.81-1.32)
Q3	1.28 (1.06-1.56)*	1.32 (1.08-1.63)*	1.22 (0.95-1.58)
Q4- Highest relative dep	1.18 (0.97-1.44)	1.16 (0.94-1.43)	1.27 (0.98-1.66)

¶ Model is adjusted for age, sex, father's Occupational Social Class (OSC), childhood smoking status, people per room in childhood home, and the following variables at age 70: OSC, smoking status, alcohol consumption and BMI

* P<0.05

Table 3: Area level socioeconomic deprivation and Hospital Anxiety and Depression score in later life, by sex of participant (IRRs and 95% CIs)

Life course model ¶	**Hospital Anxiety and Depression Score**					
	Total		**Anxiety**		**Depression**	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**
Critical Periods						
Childhood						
Ref- Lowest relative dep.	1.00	1.00	1.00	1.00	1.00	1.00
Q2- Highest relative dep.	1.11 (0.92-1.35)	1.12 (0.93-1.35)	1.16 (0.94-1.44)	1.19 (0.98-1.43)	1.05 (0.83-1.32)	0.99 (0.76-1.29)
Early Adulthood						
Ref- Lowest relative dep.	1.00	1.00	1.00	1.00	1.00	1.00
Q2- Highest relative dep.	1.14 (0.94-1.39)	1.11 (0.92-1.33)	1.08 (0.87-1.35)	1.12 (0.92-1.35)	1.22 (0.97-1.55)	1.09 (0.83-1.42)
Adulthood						
Ref- Lowest relative dep.	1.00	1.00	1.00	1.00	1.00	1.00
Q2- Highest relative dep.	1.08 (0.88-1.34)	1.14 (0.95-1.37)	1.22 (0.97-1.54)	1.08 (0.90-1.30)	0.92 (0.72-1.18)	1.32 (1.03-1.71)*
Later Adulthood						
Ref- Lowest relative dep.	1.00	1.00	1.00	1.00	1.00	1.00
Q2- Highest relative dep.	1.02 (0.83-1.26)	1.09 (0.90-1.32)	1.14 (0.90-1.44)	1.08 (0.89-1.31)	1.19 (0.92-1.55)	1.12 (0.85-1.46)
Accumulation						
Ref- Lowest relative dep.	1.00	1.00	1.00	1.00	1.00	1.00
Q2- Highest relative dep.	1.30 (1.05-1.61)*	1.22 (1.01-1.48)*	1.41 (1.10-1.80)*	1.23 (1.01-1.50)*	1.19 (0.92-1.55)	1.22 (0.93-1.61)

¶ Model is adjusted for age, sex, father's Occupational Social Class (OSC), childhood smoking status, people per room in childhood home, and the following variables at age 70: OSC, smoking status, alcohol consumption and BMI

* P<0.05

Table 4: Area level Green space and Hospital Anxiety and Depression score in later life (IRRs and 95% CIs)

Life course model ¶	**Hospital Anxiety and Depression Score**		
	Total	**Anxiety**	**Depression**
Critical Periods			
Childhood			
Ref – lowest green space	1.00	1.00	1.00
Q2	0.90 (0.75-1.07)	0.88 (0.72-1.06)	0.94 (0.74-1.19)
Q3	0.93 (0.78-1.11)	0.93 (0.77-1.13)	0.90 (0.71-1.15)
Q4 – highest green space	0.97 (0.81-1.16)	0.91 (0.76-1.10)	1.06 (0.84-1.34)
Adulthood			
Ref – lowest green space	1.00	1.00	1.00
Q2	1.01 (0.85-1.21)	1.13 (0.93-1.36)	0.80 (0.63-1.01)
Q3	0.96 (0.80-1.15)	1.02 (0.84-1.24)	0.84 (0.66-1.06)
Q4 – highest green space	0.92 (0.76-1.11)	0.93 (0.76-1.14)	0.88 (0.69-1.12)
Later Adulthood			
Ref – lowest greens pace	1.00	1.00	1.00
Q2	1.01 (0.84-1.21)	1.00 (0.93-1.22)	1.04 (0.82-1.32)
Q3	1.09 (0.91-1.30)	1.03 (0.85-1.26)	1.19 (0.94-1.50)
Q4 – highest green space	1.01 (0.84-1.22)	1.04 (0.85-1.25)	0.98 (0.77-1.24)
Accumulation			
Ref – lowest greens pace	1.00	1.00	1.00
Q2	0.99 (0.83-1.19)	1.00 (0.83-1.22)	0.96 (0.75-1.21)
Q3	0.99 (0.82-1.18)	1.00 (0.82-1.21)	0.94 (0.74-1.19)
Q4	0.97 (0.81-1.16)	0.95 (0.78-1.15)	0.98 (0.78-1.24)

¶ Model is adjusted for age, sex, father's Occupational Social Class (OSC), childhood smoking status, people per room in childhood home, and the following variables at age 70: OSC, smoking status, alcohol consumption and BMI

* P<0.05

Table 5: Area level green space and Hospital Anxiety and Depression score in later life, by area level deprivation in childhood (IRRs and 95% CIs)

Life course model ¶	**Hospital Anxiety and Depression Score**					
	Total		**Anxiety**		**Depression**	
	Lower Deprivation¥	Higher Deprivation	Lower Deprivation	Higher Deprivation	Lower Deprivation	Higher Deprivation
Critical Periods						
Childhood						
Higher Absolute Green space	1.09 (0.91-1.30)	0.91 (0.76-1.10)	1.14 (0.96-1.38)	0.83 (0.67-1.01)	0.97 (0.76-1.24)	1.09 (0.85-1.39)
Adulthood						
Higher Absolute Green space	0.95 (0.80-1.14)	0.90 (0.74-1.08)	1.01 (0.84-1.21)	0.83 (0.68-1.01)	0.85 (0.68-1.09)	1.05 (0.82-1.34)
Later Adulthood						
Higher Absolute Green space	1.01 (0.84-1.20)	1.07 (0.89-1.30)	1.02 (0.85-1.23)	1.03 (0.83-1.27)	0.98 (0.77-1.25)	1.15 (0.90-1.46)
Accumulation						
Higher Absolute Green space	1.04 (0.87-1.25)	0.91 (0.75-1.10)	1.14 (0.94-1.38)	0.81 (0.66-0.99)*	0.89 (0.70-1.14)	1.11 (0.88-1.41)

¶ Model is adjusted for age, sex, father's Occupational Social Class (OSC), childhood smoking status, people per room in childhood home, and the following variables at age 70: OSC, smoking status, alcohol consumption and BMI

¥ Lower deprivation is defined as below the median childhood area level deprivation; higher deprivation is defined as above the median childhood area level deprivation

* P<0.05

Figure 1. Relative ranking by (a) area-level social deprivation and (b) green space measures for neighbourhoods across the study area 1931-2011.

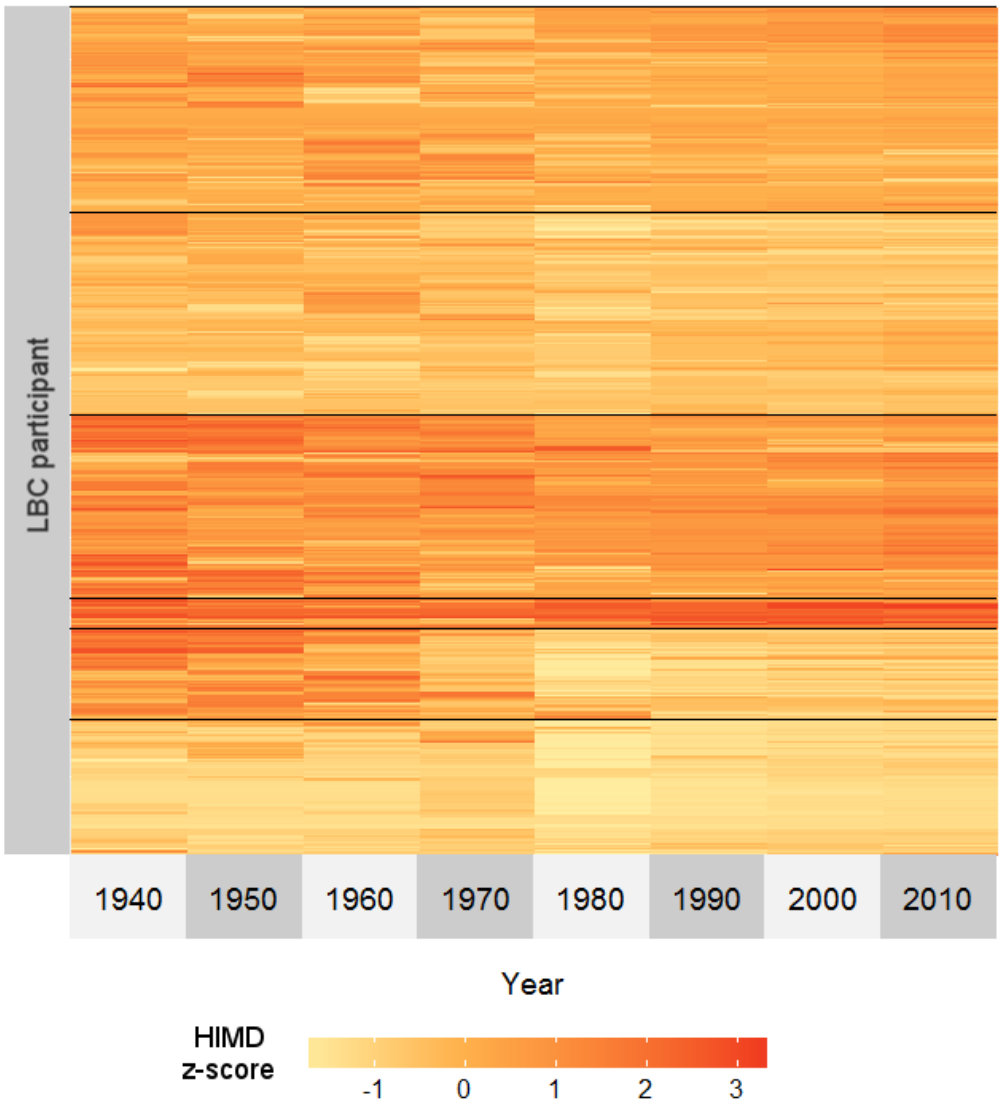
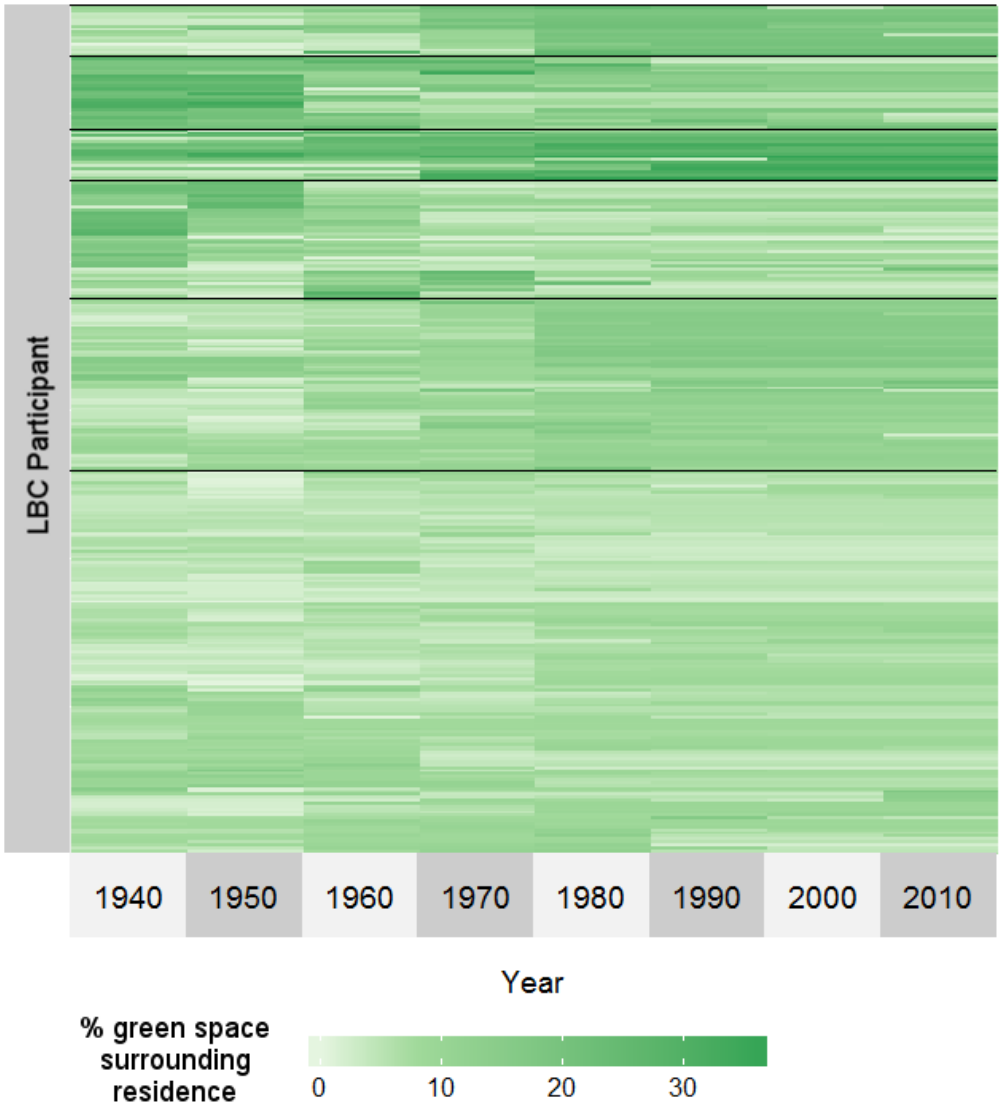
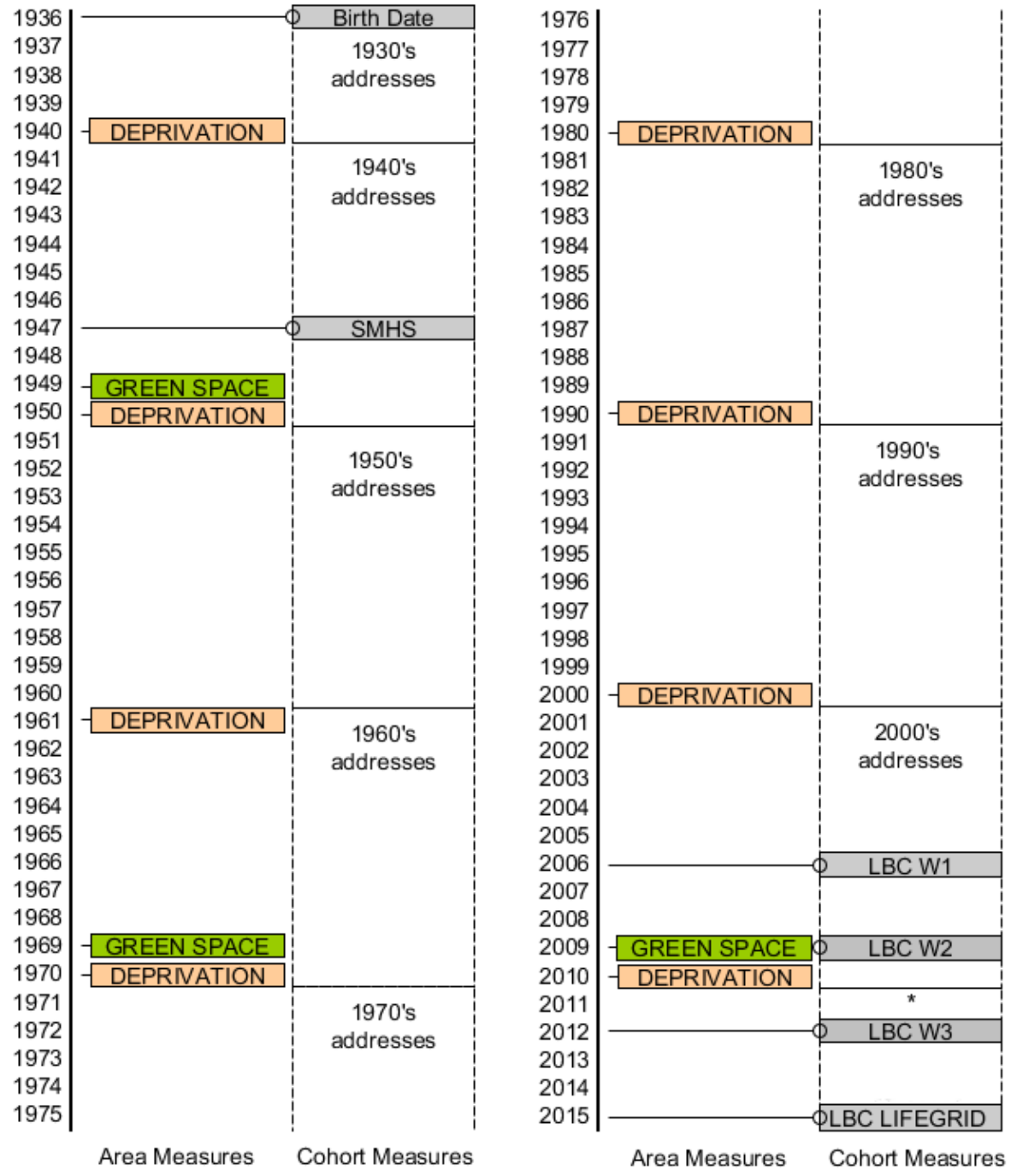


Figure 2: Heatmap for a sample of participants in the Lothian Birth Cohort (1936) according to their (a) neighbourhood social deprivation conditions and (b) green space provision, 1931-2011.



Supplementary Electronic Material

Supplementary Figure 1: Overview of the cohort and geographical information available at each time point



Supplementary Table 1: Overview of data used to construct the historical index of multiple deprivation

Variable	Decade	Definition	Geographic level	Source
Overcrowding	1930	Percentage of population living more than 2 per room	Wards	1931 Census
	1940	*Estimated* using linear interpolation of 1930 and 1950 data	Wards	1931 census and 1951 census
	1950	Percentage of population living more than 2 per room	Wards	1951 Census
	1960	Percentage of population living more than 1.5 per room	Wards	1961 Census
	1970	Percentage of population living more than 1.5 per room	Wards	1971 Census
	1980	Percentage of population living more than 1.5 per room	District Wards	1981 Census
Population Density	1930	Persons per acre	Wards	1930 MOH Report
	1940	Persons per acre	Wards	1940 MOH Report
		Persons per acre	Districts	1946 survey in Abercrombie report
	1950	Persons per 100 acres Persons per acre calculated	Wards	1951 Census
	1960	Persons per acre	Wards	1961 Census
	1970	Persons per hectare Persons per acre calculated	Wards	1971 Census
	1980	Persons per acre calculated	Postcode Sectors	1981 Census
Infant Mortality	1930	Number of infant deaths (<1 year) per 1000 births	Wards	1930 MOH Report
	1940	Number of infant deaths (<1 year) per 1000 births	Wards	1940 MOH Report
	1950	Number of infant deaths (<1 year) per 1000 births	Wards	1950 MOH Report
	1960	Number of infant deaths (<1 year) per 1000 births	Wards	1960 MOH Report
	1970	Number of deaths and number of live births for registration year 1974-1976, combined Number of infant deaths per 1000 calculated	Wards	National Records of Scotland
	1980	Number of deaths and number of live births for registration years 1980-1982, combined Number of infant deaths per 1000 calculated	Wards	National Records of Scotland
Amenities	1930	*Estimated* from model based on regression of amenities indicator and MOH report data for 1951 and 1961*	Wards	1930 MOH report
	1940	*Estimated* from model based on regression of amenities indicator and MOH report data for 1951 and 1961	Wards	Medical Officer Health Report 1930, 1938, 1950, 1960 and 1951/1961 Census

	1950	Percentage of households that share use/entirely without piped water supply, cooking stove/range, kitchen sink, water closet and fixed bath	Wards	1951 Census
	1960	Percentage of households that share use/entirely without cold water, hot water, fixed bath and toilet	Wards	1961 Census
	1970	Percentage of households that share use of hot water, fixed bath/shower and inside flush toilet	Wards	1971 Census
	1980	Percentage of households that share use/entirely without bath and water closet	District Wards	1981 Census
Tenure	1930	*Estimated* by using 1940 data	Districts	1946 survey in Abercrombie report
	1940	Percentage of households that rent their accommodation	Districts	1946 survey in Abercrombie report
	1950	*Estimated* by linear interpolation of 1940 and 1960 data	Wards	A and P and census
	1960	Percentage of households that rent their accommodation[2]	Wards	1961 Census
	1970	Percentage of households that rent their accommodation[2]	Wards	1971 Census
	1980	Percentage of households that rent their accommodation	District Wards	1981 Census

Supplementary Table 2: Area level socioeconomic deprivation and Hospital Anxiety and Depression score in later life (IRRs and 95% CIs), unadjusted results

Life course model ¶	**Hospital Anxiety and Depression Score**		
	Total	**Anxiety**	**Depression**
Critical Periods			
Childhood			
Ref- Lowest relative dep.	-	-	-
Q2	0.99 (0.83-1.21)	1.12 (0.94-1.23)	0.93 (0.74-1.18)
Q3	0.96 (0.80-1.15)	1.04 (0.86-1.27)	0.81 (0.63 -1.03)
Q4- Highest relative dep.	1.22 (1.03-1.46)*	1.21 (1.00-1.47)*	1.23 (0.98-1.55)
Early Adulthood			
Ref- Lowest relative dep.	-	-	-
Q2	1.01 (0.84-1.21)	1.02 (0.84-1.24)	1.01 (0.78-1.28)
Q3	1.16 (0.97-1.38)	1.18 (0.97-1.43)	1.11 (0.87-1.41)
Q4- Highest relative dep	1.21 (1.01-1.44)*	1.13 (0.93-1.38)	1.36 (1.08-1.72)*
Adulthood			
Ref- Lowest relative dep.	-	-	-
Q2	1.08 (0.90-1.29)	1.03 (0.85-1.26)	1.17 (0.92-1.49)
Q3	1.15 (0.96- 1.37)	1.11 (0.91-1.35)	1.22 (0.96-1.56)
Q4- Highest relative dep	1.11 (0.93-1.34)	0.98 (0.81-1.19)	1.15 (0.90-1.47)
Later Adulthood			
Ref- Lowest relative dep.	-	-	-
Q2	1.05 (0.88-1.26)	0.89 (0.74 – 1.12)	1.33 (1.05-1.68)*
Q3	1.08 (0.90-1.30)	1.06 (0.87-1.28)	1.13 (0.89-1.44)
Q4- Highest relative dep	1.00 (0.84-1.21)	0.98 (0.81-1.19)	1.08 (0.84-1.37)
Accumulation			
Ref- Lowest relative dep.	-	-	-
Q2	0.96 (0-80-1.15)	0.89 (0.74 – 1.09)	1.10 (0.86-1.40)
Q3	1.25 (1.04-1.49) *	1.24 (1.03 -1.50)*	1.25 (0.98-1.59)
Q4- Highest relative dep	1.15 (0.96-1.37)	1.08 (0.89-1.31)	1.30 (1.02-1.65)*

* P<0.05

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